CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-146

Bear Mountain Fault Zone North of Auburn

May 16, 1983

1. Name of faults

Swain Ravine, Spenceville, and Dewitt segments of the northern Bear Mountain fault zone (figure 1).

2. Location of faults

Bangor, Wheatland, Grass Valley, and Auburn 15-minute quadrangle, Butte, Yuba, Nevada, and Placer Counties. Detailed segments of the Swain Ravine, Spenceville, and Dewitt fault zones are mapped in the Bangor, Loma Rica, Camp Far West, Gold Hill, and Auburn 7.5-minute quadrangles.

3. Reason for evaluation

Part of the 10-year fault evaluation program (Hart, 1980).

4. References

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5. Review of Available Data

The Foothills fault system in the western Sierra Nevada, first named by Clark (1960), was not considered to be recently active prior to the 1975 M5.7 Oroville earthquake. Surface fault rupture along the Cleveland Hill fault zone was associated with the Oroville earthquake, and, subsequently, was zoned for Special Studies on January 1, 1977. As a result of the Oroville earthquake, geotechnical investigations for the proposed Auburn Dam were greatly expanded. Woodward-Clyde Consultants (WCC), under contract for the U.S. Bureau of Reclamation (USBR), conducted detailed studies of the Auburn damsite, but also investigated earthquake hazards elsewhere in the western foothills of the Sierra Nevada. Thus, significant new data on recently active faults in the foothills were developed. Selected segments of the Foothills fault system from Sonora north to near Oroville will be evaluated in three Fault Evaluation Reports (FER). This FER will evaluate fault zones north of Auburn: the Swain Ravine, Spenceville, and Dewitt fault zones (figure 1).

The Foothills fault system consists of the Melones fault zone on the east and the Bear Mountain fault zone on the west (Clark, 1960, 1964, 1976; Cebull, 1972; Duffield and Sharp, 1975). Faults within the FER study area may represent a northerly extension of the Bear Mountain fault zone. The Bear Mountain fault zone, as with other segments of the Foothills fault system, was generated by eastward plate convergence and subduction during early Mesozoic time (Hamilton, 1969; Schweickert and Cowan, 1975; Clark, 1976). This episodic period of plate convergence produced the dominant structural features in the western Sierran foothills and the Foothills fault system. In general, structural elements that comprise the Foothills fault system are subparallel to regional foliation and cleavage. This has resulted in a strong structural grain dominated by planar elements that strike north-northwest and generally dip steeply east.

Superimposed on this compressional structural fabric is a late-Tertiary to present period of east-west extension (Alt, et al., 1977). This east-west extension has resulted in high-angle normal faults that occur along pre-existing Paleozoic and Mesozoic structures (Alt, et al., 1977). However, Alt, et al. found evidence indicating that late-Cenozoic activity has not occurred along all pre-existing faults of the Foothills fault system.

Rock types in the FER study area consist predominately of Late Jurassic metavolcanic rocks of the Smartville ophiolite, minor outcrops of Cretaceous granitoid rocks of the Swedes Flat pluton, and sparse, isolated patches of late Cenozoic gravels (CDWR, 1979; Burnett and Jennings, 1962; Wagner, et al., 1981; Alt et al., 1977). A characteristic problem with evaluating recent fault activity in the western Sierran foothills is the general lack of Tertiary and Quaternary material overlying much of the Mesozoic bedrock.

Remnants of a paleo-B soil horizon developed in Mesozoic bedrock locally occur in the western Sierran foothills. This paleosol is thought by WCC to have formed about 100,000 years B.P. (Swan and Hanson, 1977). However, the U.S. Geological Survey (1978) and Borchardt, et al. (1980) suggest that the foothills paleosol was actively developing from about 140,000 years to 10,000 years B.P. They reason that the paleosol probably began to form about 100,000 years to 140,000 years ago and continued to develop until eroded or deeply buried by younger deposits. Therefore, its age extends to the age of the overlying erosion surface or deposits. In many places, the overlying deposit is what Borchardt, et al. term the foothills colluvium, a relatively unweathered colluvium thought to have formed about 9,000 years B.P. (Swan and Hanson, 1977; Borchardt, et al., 1980).

Land surfaces in the FER study area generally have not been altered by development or agriculture. Topography in the study area is characterized by linear ridges and valleys reflecting the strong north to northwest-trending Mesozoic structural fabric. Massive landsliding in the area generally is not widespread, but local soil creep and expansive soils have affected or modified soil-bedrock relationships.

SWAIN RAVINE FAULT ZONE

The Swain Ravine fault zone is a prominent, north-northwest trending topographic lineament that coincides with a Mesozoic fault zone. The Cleveland Hill fault, which ruptured during the 1975 Oroville earthquake, is part of the Swain Ravine fault zone.

Cleveland Hill Fault Zone

Surface fault rupture along the Cleveland Hill fault zone was associated with the 1975 M5.7 Oroville earthquake (Hart and Rapp, 1975; Clark, et al., 1976). Segments of the Cleveland Hill fault that ruptured during the Oroville earthquake and subsequent aftershocks were zoned for Special Studies in January 1977. Previously zoned segments of the Cleveland Hill fault will not be evaluated in this FER, but it is illustrative to review the characteristics of this fault zone in order to compare it with other potentially active faults along the western Sierran foothills.

The Cleveland Hill fault is part of the Swain Ravine lineament (CDWR 1979; Schwartz, et al., 1977). The sense of offset along the Cleveland Hill fault is normal, down to the west along several fault strands. Surface displacement along the fault after the Oroville earthquake was oblique slip, with maximum right-lateral strike-slip displacement of 3-4 cm and maximum down-to-the-west vertical displacement of 4-5 cm (Hart and Rapp, 1975). Fault plane solutions indicate down-to-the-west normal faulting along a north-trending, west-dipping fault. Aftershock data confirms a west-dipping fault zone (Lester, et al., 1975). The right-lateral component of offset along the Cleveland Hill fault may represent a near surface phenomenon. Perhaps the apparent right-lateral component is the result of east-west extension along a north-northwest trending fault (see Clark, et al., 1976, p. 1103). An alternative explanation assumes that the surface faulting propagated from south to north along left-stepping en echelon fractures.

Several trenches have been excavated along traces of the Cleveland Hill fault zone by WCC, CDWR, and USBR (figures 1, 3a). WCC summarized the evidence for recent faulting observed during trenching:

(a) Surficial deposits and/or soil horizons are displaced or discontinuous across the clay gouge bands that define the fault planes.

(b) Colluvial deposits are vertically displaced from less than 1 inch to as much as 1.5 feet.

(c) Paleo-B soil horizons are vertically displaced from less than 1 inch to approximately 2 feet. These values represent cumulative displacements resulting from multiple events (Page, et al., 1978).

(d) Slickensided surfaces and shears extend from bedrock faults into overlying colluvium and/or soils.

(e) Contact between bedrock and overlying Quaternary deposits and soils generally has a step pattern across the faults.

(f) Paleo-B soil horizon in many places is thicker over the clay gouge zones than over less deformed or unaltered bedrock.

Most of the trenches excavated across the Cleveland Hill fault contained evidence for faulted bedrock, but a sense of systematic recent offset was weak. Akers and McQuilkin (1975) point out that trenches across surface ruptures along the Cleveland Hill fault showed that surface cracks "...could be seen penetrating the soil layer, (but) they could not be traced into the underlying materials. No vertical displacement of the bedrock surface was evident in the three logged trenches (figure 3a, trenches A-D). The limited extent of the soil-bedrock contact exposed in the trenches and the natural irregularity of the bedrock surface, however, would tend to mask vertical displacements of the small magnitude at (the) ground surface." Additional trenches excavated by DWR along traces of the Cleveland Hill fault zone show various degrees of evidence for recent activity, ranging from down-to-the-west offset colluvium coincident with down-to-the-west bedrock faulting (figures 4a,4c), to an alluvial unit offset about 1.2 inches (down to the west) with about 11 feet of unfaulted alluvium overlying the faulted alluvium (T_8). Woodward-Clyde estimated a slip rate of 1.5 feet per 100,000 years along the Cleveland Hill fault, which is about 0.005 mm/yr (CDWR, 1979, p. 74).

Orange Road Site

The Orange Road site is located on the Swain Ravine fault zone, about 2-1/2 miles south of the southernmost ground cracks observed along the Cleveland Hill fault zone (figure 3a). A 1,500-foot-long zone of extension cracks was observed at the Orange Road site and is assumed to have been associated with the Oroville earthquake (Schwartz, et al. 1977). The cracks were extensional with no vertical component of displacement observed.

The Orange Road site is of considerable importance because a late-Cenozoic channel deposit crosses the fault zone, providing a very rare opportunity to evaluate late-Cenozoic displacement. The Tertiary age of this east-west-trending channel deposit was based on Lindgren and Turner (1895). Aune (1976) suggests that this channel deposit may be correlative with Plio-Pleistocene Laguna or Tehama Formations (Schwartz, et al., 1977). Mapping by CDWR indicates that faulting has not measurably offset the northern contact of this channel deposit (CDWR, 1979; McJunkin, 1978; figure 3a). McJunkin (p.c.

1983) acknowledges that poor exposures of the channel deposit would allow up to about 20 feet of fault offset to go unnoticed. Mapping by WCC also does not show the northern contact of the channel deposit to be clearly offset (Schwartz, et al., 1977, p. A-129). Trenches across ground cracks observed at the Orange Road site were excavated by WCC (Schwartz, et al., 1977) (figure 3a). A normal fault, down to the east, was exposed in trench T_2 (figure 5a). A paleo-B soil horizon located east of the fault is truncated at the east-dipping shear, and was not observed on the west, or upthrown, side of of the fault (figure 5a). The shear extends to the surface, and colluvium seems to be thicker on the east side of the fault. The fault zone exposed in T_2 is within Mesozoic metavolcanic rocks.

Trench T_3, located 800 feet north of T_2, is a very critical exposure. WCC, based on this trench and a boring located west of the trench, postulated about 14 feet of down-to-the-east vertical displacement of the late-Cenozoic channel deposit. A steeply east-dipping fault offsets metavolcanic rocks overlain by the late-Cenozoic channel deposit on the west against late-Cenozoic channel deposits on the east (figure 5a). The channel deposits have an apparent easterly dip east of the fault and dip in an apparent westerly direction (downslope) west of the fault.

Geologists from USACE (Trent, 1976) dispute WCC's identification of late-Cenozoic channel deposits in trench exposure T_3. Trent interprets the material to be highly weathered Mesozoic metavolcanic rocks. The metavolcanic channel deposit contact in the western part of trench T_3 is only a color change from yellowish tan to dark reddish brown with no textural variation between the two units. The overlying paleo-B soil horizon does not seem to be offset by the fault, although soil-bedrock relationships are obscured at this locality by soil creep.

Trench T_4, located north of T_3 across a steep gully, exposed a steeply east-dipping fault that offsets metavolcanic rock on the west against east-dipping channel deposits on the east (Schwartz, et al., 1977; figure 5b). Trent (1976) agrees that east-dipping channel deposits occur at the very eastern end of the trench, but again questions the identification of channel deposits just east of the fault (units 12, 13, 14, 15 of WCC; figure 5b), suggesting instead that these units are highly weathered metavolcanic rocks. Downhill creep apparently has deflected the fault plane downslope and has disturbed soil-bedrock relationships. However, faulting does not seem to have offset the paleo-B soil horizon (Schwartz, et al., 1977).

WCC assigned the fault exposed in trench T_2 as active (USBR criterion-active within last 100,000 years) with a confidence rating of 10. However, out of nine trenches excavated within a distance of 1,000 feet, this was the only trench that clearly exposed an offset paleo-B soil horizon. In addition, the fault dips to the east, while trenches excavated across traces of the Cleveland Hill fault dipped systematically to the west.

Parks Bar-Dry Creek Site

The USACE (1977; Woodward-Clyde, 1976) investigated segments of the Swain Ravine fault zone just north of the Yuba River in the Parks Bar-Dry Creek area (figures 1,2a). USACE excavated five trenches across segments of the Swain Ravine lineament, and, although generally east-dipping bedrock faults were exposed, no evidence of Quaternary faulting was observed. A Tertiary channel deposit crosses segments of the Swain Ravine fault zone about 3,000 feet north of the Yuba River. Tertiary gravels exposed by hydraulic mining were inspected by WCC, and no evidence of faulting was observed; however, WCC points out that exposures were not continuous.

SPENCEVILLE FAULT ZONE

The Spenceville fault zone is a prominent, northwest-trending lineament that merges with the Swain Ravine fault zone about 7 miles south of the Yuba River (figure 2a). Like the Swain Ravine fault zone, the Spenceville fault zone is a very straight lineament that is associated with a Mesozoic fault zone.

WCC (Schwartz, et al., 1977) exposed evidence of possible Holocene faulting at the Spenceville exploration site (figure 6). Trench T_{1a} exposed a northwest-trending, west-dipping fault that offsets massive greenstone on the east against foliated metavolcanic rock on the west. A paleo-B soil horizon, which extends across the fault zone, thickens across the principal shear (figure 7a). The main fault plane (N55°W, 67°SW), with dip-slip slickensides, splays into west- and east-dipping shears. The west-dipping shear offsets the paleo-B horizon and in the northern trench wall extends into the overlying Holocene colluvium (Borchardt, et al., 1980), although the colluvium-paleo-B contact is not offset (figure 7a). Trench T_2, located just north of T_{1a}, exposed a N30°W-trending, vertically dipping fault that seems to offset the paleo-B soil horizon, down to the west. No shears were observed in the paleo-B horizon (figure 7b). Borchardt, et al. (1980) concluded that this step-like feature is not necessarily related to Holocene faulting but could have been formed as the result of preferential movement of groundwater toward the fault plane.

Trench T_3 exposed a 3'- to 4'-wide shear zone striking northwest and dipping 70° to 75°SW (figure 7b). The western shear changes dip to about 25°E and extends into the Holocene colluvium, although the colluvium-paleo-B contact is not offset. The paleo-B soil horizon is truncated at the western shear. East-dipping shears in the paleo-B soil horizon were observed in the corresponding position in the north wall of T_3, but the bedrock-paleo-B contact and the paleo-B-colluvium contact were not offset. Sub-horizontal slickensides were observed along shears in the paleo-B soil horizon in the north wall of T_3. These sub-horizontal slickensides along the shallow east-dipping shears, and the lack of bedrock-soil contact offsets, suggest that processes other than Holocene-active faulting, such as soil creep or expansive soil, may have generated the shears in the paleo-B horizon and colluvium. Schwartz, et al. (1977) assessed the Spenceville site as active (USBR criterion), with a reliability factor of 8, based on the faulted paleo-B soil horizon observed in trench T_{1a}. Adjacent trenches excavated along the trend of the fault exposed in T_{1a} did not expose similar soil-bedrock relationships. Cumulative post-paleo-B vertical stratigraphic separation in T_{1a} was estimated to be less than 2 feet (Schwartz, et al., 1977, p. A-196). This magnitude of offset corresponds to a slip rate of about 0.005mm/yr.

DEWITT LINEAMENT

The Dewitt lineament is a northwest-trending topographic lineament located from the Bear River southeast to Auburn (figures 2b, 8). Clark and Huber (1975) mapped shear zones exposed along the Bear River coincident with the Dewitt lineament, indicating that it is a Mesozoic fault zone.

Hubbard Road Site

The Hubbard Road site is located southeast of Big Hill, near Dry Creek (figure 8). Woodward-Clyde excavated two trenches across two segments of the Dewitt fault zone (Schwartz, et al., 1977; figure 8). Trench T_2 exposed evidence of an offset paleo-B soil horizon that has been displaced about 15cm in a normal sense, down to the west (figure 9). Downslope creep and expansive soil affect soil-fault relationships at the site, so there is some question as to the cause of the feature exposed in T_2. Borchardt, et al. (1980) have concluded that post-paleo-B faulting produced the feature observed in T_2. However, significant Holocene displacement probably has not occurred along this fault because: 1) although the fault dips to the west (down to the west displacement), the ground slopes to the east; (2) there is no geomorphic evidence of a west-facing scarp; and, (3) colluvium should be thicker on the down-thrown block, but the opposite was observed in T_2 (figure 9). Similar soil-fault relationships were not observed in trench T_1.

Bean Road and St. Joseph Sites

The Bean Road and St. Joseph exploration sites are located along parallel strands of the Dewitt lineament zone (figure 8). Trenches excavated at both sites exposed bedrock faults, but evidence for recent faulting was not observed. However, only occasional patches of a paleo-B soil horizon were preserved at these sites, so WCC (Schwartz, et al., 1977) classified the faults as indeterminate (inactive) (Bean Road site) and indeterminate (St. Joseph site).

SEISMICITY AND CRUSTAL MONITORING

The northern Foothills fault system has a pattern of low-level seismicity (Cramer, et al., 1978; Marks and Lindh, 1978, Eaton and Simirenko, 1980). With the exception of the 1975 Oroville earthquake and aftershock sequence and seismicity in the Rocklin pluton, very little historic seismicity has occurred along the northern Bear Mountain fault zone in the FER study area (figure 10). However, seismic monitoring of this region has not been extensive, so very little information regarding seismicity is available and reliable conclusions are difficult to make.

First-order releveling surveys across segments of the Foothills fault system indicate that vertical deformation has occurred since initial surveys performed in 1947 (Bennett, 1978). This evidence of crustal strain is associated with recognized pre-Cenozoic faults within the two main branches of the Foothills fault system. Approximately 20 mm of down-to-the-west vertical deformation occurred along the Bear Mountain fault zone near Auburn between 1969 and 1977 (Bennett, 1978). This deformation occurred in a zone about 1-1/2 miles wide. Crustal strain associated with the Foothills fault system typically occurs in a zone up to four miles wide, indicating that strain is distributed over a broad zone rather than along discrete, well-defined faults.

A releveling survey across the northern extension of the Bear Mountain fault zone near Smartville was made by Bennett in 1979 (Bennett, 1983). This survey was compared with leveling surveys made in 1934 and 1949. Results indicate that no significant vertical deformation has occurred along this segment of the Bear Mountain fault zone.

6. Air photo interpretation

The results of brief air photo interpretation by this writer along segments of the Swain Ravine, Spenceville, and Dewitt fault zones are summarized on figures 3a, 3b, 6, and 8. Because of the limited time allotted for this FER, air photo interpretation was generally limited to verifying faults mapped by others at site specific localities.

The Swain Ravine, Spenceville, and Dewitt fault zones are characterized by features such as linear valleys, ridges, drainages, and aligned saddles. These large-scale geomorphic features reflect a near vertical northwest-trending structural fabric formed in Mesozoic time and are primarily erosional. These features are generally well-defined within a regional context, but are much less well-defined in detail. Geomorphic features characteristic of recent, systematic faulting were not observed. The absence of these geomorphic features indicates that either Holocene faulting has not occurred or that slip rates along individual faults are very low.

SWAIN RAVINE FAULT ZONE

Cleveland Hill fault

The Cleveland Hill fault is shown in figure 3a. The geomorphic expression of late-Quaternary faulting along the Cleveland Hill fault is generally very subtle or absent. A subtle west-facing scarp, linear vegetation contrasts, aligned saddles, and linear drainages in section 7, T18N, R5E delineate well-defined segments of the Cleveland Hill fault zone and are coincident with surface rupture associated with the 1975 Oroville earthquake (figure 3a). However, most geomorphic features defining segments of the Cleveland Hill fault zone are not very well-defined and are probably erosional. Clark, et al. (1976) summarized the geomorphic expression along the Cleveland Hill fault zone as follows: "There are few topographic features related to faulting in the rupture zone. The most prominent scarp trends from section 6, is 1 to 1-1/2 m high and is followed at its base for about 100 m by the south break. The scarp has been considerably rounded by erosion and diverges southeastward from the rupture. It may be purely erosional in origin, reflecting differential rates of weathering of the underlying metavolcanic rocks. In a few places, both to the north and to the south of this pronounced scarp, the new fractures follow either faint scarps or slight breaks in slope."

Orange Road Site

Geomorphic features characteristic of recent faulting are not well-defined at the Orange Road site within the Swain Ravine fault zone (figure 3a). Discontinuous faults are suggested by a linear drainage and topographic saddle at and just south of the exploration site (figure 3a). However, there is no geomorphic evidence of recent faulting along a northward projection of the faults observed at the Orange Road site.

The Swain Ravine fault zone just south of the Orange Road exploration site is defined by a northwest-trending zone of geomorphic features suggesting right-lateral strike-slip faulting (figures 3a, 3b). Right-laterally deflected drainages, broad linear troughs, linear drainages, and well-defined tonal lineaments characterize this seven-mile-long segment. Recent faulting is suggested by the well-defined tonal lineaments and deflected drainages, but it is more likely that these features are due to differential erosion along an old fault zone. Ephemeral geomorphic features characteristic of Holocene-active faulting were not observed by this writer.

SPENCEVILLE FAULT ZONE

The Spenceville fault zone merges with the Swain Ravine fault zone west of the Horsehoe Flat area and continues southeast as a major structural feature (figure 2a). The Spenceville exploration site of WCC is characterized by a northwest-trending linear valley. Linear vegetation contrasts and a subtle west-facing scarp may delineate recently active faults (figure 6). Discontinuous linear vegetation contrasts within the linear valley characterize traces of the Spenceville fault zone south of the Spenceville site. Geomorphic evidence of recent faulting, with the exception of discontinuous tonal lineaments and a subtle W-facing scarp, was not observed along the Spenceville fault zone. A large right-lateral deflection of the Bear River along the south end of the Spenceville fault zone (figure 2a) apparently is erosional, because there is no evidence of systematic offset of drainages elsewhere along the fault trend.

DEWITT FAULT ZONE

The Dewitt fault zone trends from the Bear River southeast through Auburn (figure 2b). The Dewitt fault zone is generally similar to the Swain Ravine and Spenceville fault zones, although it is not as well-defined. Near the Hubbard Road exploration site, Dry Creek is deflected right-laterally, but there is no evidence of systematic lateral or vertical offset of most drainages (figure 8). Faults in the Dewitt fault zone are delineated principally by linear tonal contrasts and a very subtle northeast-facing scarp at the Hubbard Road site. Hummocky ground at the WCC trench localities indicates active soil creep, and locally small landslides have occurred along the course of Dry Creek. Sharp tonal lineaments associated with scarps were observed along the north side of Dry Creek, but they are not continuous, and Dry Creek is not offset where it is crossed by one of the lineaments (figure 8). Right-laterally deflected drainages east of Big Hill are probably erosional, and no geomorphic evidence of recent faulting was observed in the linear saddle east of Big Hill along the Dewitt fault zone (figure 8).

Geomorphic evidence of recent faulting at the Bean Road and St. Joseph exploration sites was not observed. Discontinuous, poorly defined linear tonal contrasts delineate the Dewitt fault zone at these sites (figure 8).

7. Conclusions

Woodward-Clyde Consultants (Alt, et al., 1977; Schwartz, et al., 1977), under contract to USBR, conducted detailed studies of the Foothills fault system with respect to seismic safety for the proposed Auburn dam. Regional studies along the northern extension of the Bear Mountain fault zone revealed evidence for late-Cenozoic extensional faulting superimposed along prominent regional lineaments that define fault zones initially formed during the Mesozoic Era. A strong north- to northwest-trending structural fabric in Mesozoic-age metamorphic rocks dominates landforms in the western Sierran foothills, but prominent, northwest-trending lineaments, the Swain Ravine, Spenceville, and Dewitt lineaments, stand out (figures 2a, 2b). Geologic investigations have demonstrated that the Swain Ravine, Spenceville, and Dewitt lineaments are significant zones of deformation generated during episodes of Mesozoic compressional tectonism (Clark and Huber, 1975; Schwartz, et al., 1977).

SWAIN RAVINE FAULT ZONE

Surface fault rupture associated with the 1975 M5.7 Oroville earthquake occurred along the Cleveland Hill fault, which is considered a part of the Swain Ravine fault zone. First motion studies, aftershock data, and detailed geologic studies, which included trenching along the Cleveland Hill fault, confirm that the Oroville earthquake was generated along a north-trending, west-dipping normal fault. Trench data and geomorphic expression of the Cleveland Hill fault indicate that previous extensional faulting has occurred during Quaternary time. However, geomorphic expression of Holocene extensional faulting along the Cleveland Hill fault zone is very subtle (Clark, et al., 1976; Hart and Rapp, 1975), and in places is not well-defined (figure 3a).

The Orange Road site, located along the Swain Ravine fault zone, revealed evidence of possible Holocene displacement. A zone of minor extensional cracks thought to be associated with the Oroville earthquake was trenched, and a down-to-the-east normal fault associated with the ground cracks was observed (figure 5a). However, in eight additional trenches excavated at the Orange Road site, evidence for Holocene-active faulting was not clearly demonstrated. Geomorphic evidence for Holocene faulting was not observed at or to the north of the site (figure 3a). South of the site, a seven-mile-long segment of the Swain Ravine fault zone is characterized by linear drainages, some right-laterally deflected drainages and other geomorphic features superficially resembling right-lateral strike-slip faulting (figures 3a, 3b). A lack of ephemeral geomorphic features characteristic of either right-lateral strike-slip or dip-slip Holocene activity indicates that these features were formed by differential erosion.

The USACE (1977) excavated trenches along the Swain Ravine fault zone north of the Yuba River in the Parks Bar-Dry Creek area (figure 1). No evidence of Quaternary faulting was observed. A Tertiary channel deposit that crosses the Swain Ravine fault zone about 3,000 feet north of the Yuba River was not offset, although exposures were not continuous across the fault zone (Schwartz, et al., 1977).

SPENCEVILLE FAULT ZONE

WCC (Schwartz, et al., 1977; Borchardt, et al., 1980) exposed evidence of possible Holocene faulting at the Spenceville exploration site (figure 6, 7a). A west-dipping normal fault displaced a paleo-B soil horizon and shears extended into the overlying colluvium. However, conclusive evidence of Holocene faulting in additional trenches excavated adjacent to this trench was not observed. A subtle, west-facing scarp and sharp tonal lineaments characterize recent faulting at the Spenceville site (figure 6). However, north and south of this site, geomorphic evidence of recent faulting along the Spenceville fault zone is expressed only by discontinuous tonal lineaments.

DEWITT FAULT ZONE

Evidence of late-Quaternary faulting was exposed in trench T_2 at the Hubbard Road site (Schwartz, et al., 1977; figures 8, 9). A paleo-B soil horizon was offset, but it was not clear if the overlying colluvium had been offset. Downslope creep may obscure soil-fault relationships at this site. Significant Holocene faulting probably has not occurred along this fault because: 1) although the fault dips to the west and displacement is down to the west, this trench is excavated on a prominent east-facing slope; 2) there is no geomorphic evidence of a west-facing scarp; and, 3) colluvium should be thicker on the down-thrown block, but the opposite was observed in T_2.

No evidence of Holocene-active faulting was observed along the Dewitt fault zone at the Bean Road and St. Joseph exploration sites (Schwartz, et al., 1977; figure 8).

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The paucity of well-defined geomorphic features characteristic of Holocene-active normal faulting along the Swain Ravine, Spenceville, and Dewitt lineaments may be the result of either a lack of faulting during the Holocene, or very low rates of displacement (Hart and Rapp, 1975). WCC estimated that a slip rate of about 1.5 feet per 100,000 years has occurred along the Cleveland Hill fault, based on a displaced paleo-B soil horizon observed in trenches along the fault. Data observed along the Spenceville fault zone suggests that post-paleo-B faulting has not exceeded two feet (Schwartz, et al., 1977). Borchardt, et al. (1980), estimate that the foothills paleosol was an actively developing soil between 140,000 and 10,000 years B.P. Thus, an estimate of the average slip rate along the Cleveland Hill fault and the Spenceville fault zone ranges from 0.003 mm/yr-0.05 mm/yr and 0.004 mm/yr-0.06 mm/yr, respectively. Thus, if Holocene-active faults occur along the Swain Ravine and Spenceville fault zones, the slip rate is extremely low.

Crustal monitoring of the western Sierran foothills indicates that down-to-the-west deformation along the Bear Mountain fault zone is occurring near Auburn (Bennett, 1978). It is possible that this strain, reflecting current east-west extension, is distributive at the surface and is taken up along several pre-existing Mesozoic-age shear zones. Thus, a discrete zone of deformation at depth may be manifested at the surface over a wide zone, perhaps several miles in width, with minor deformation occurring along several bedrock fault zones.

Holocene faulting along the Swain Ravine, Spenceville, and Dewitt fault zones cannot be ruled out, based on investigations by WCC (Schwartz, et al., 1977; Borchardt, et al., 1980) . However, these fault zones are not well-defined in detail, and rates of displacement along individual faults probably are not large enough to produce significant amounts of surface rupture. In addition, sparse Quaternary stratigraphy along most of these fault zones severely limits the chances of meaningful active fault evaluation.

8. Recommendations

Recommendations for zoning faults for special studies are based on the criteria of sufficiently active and well-defined (Hart, 1980).

SWAIN RAVINE FAULT ZONE

Segments of the Swain Ravine fault zone south of section 7, T18N, R5E are not recommended for zoning. Well-defined geomorphic evidence of Holocene-active faulting was not observed along the fault zone. The minor cracks observed at the Orange Road site (Schwartz, et al., 1977) may or may not be associated with surface fault rupture. Well-defined geomorophic evidence supporting Holocene activity was not observed at or near the site.

SPENCEVILLE FAULT ZONE

Do not zone for special studies. Faults within this fault zone are very discontinuous and generally are not well-defined in detail. Evidence of possible Holocene faulting was observed at the Spenceville exploration site, but geomorphic evidence of Holocene faulting is very subtle at the site and is generally not well-defined elsewhere along the fault zone.

DEWITT FAULT ZONE

Do not zone for special studies. The fault zone is not well-defined in detail and evidence of significant Holocene-active faulting was not observed.

9. Report prepared by William A. Bryant, May 16, 1983.

Reviewed & approved for file - Earl W. Hart CEG 935 6/20/83

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May 16, 1983

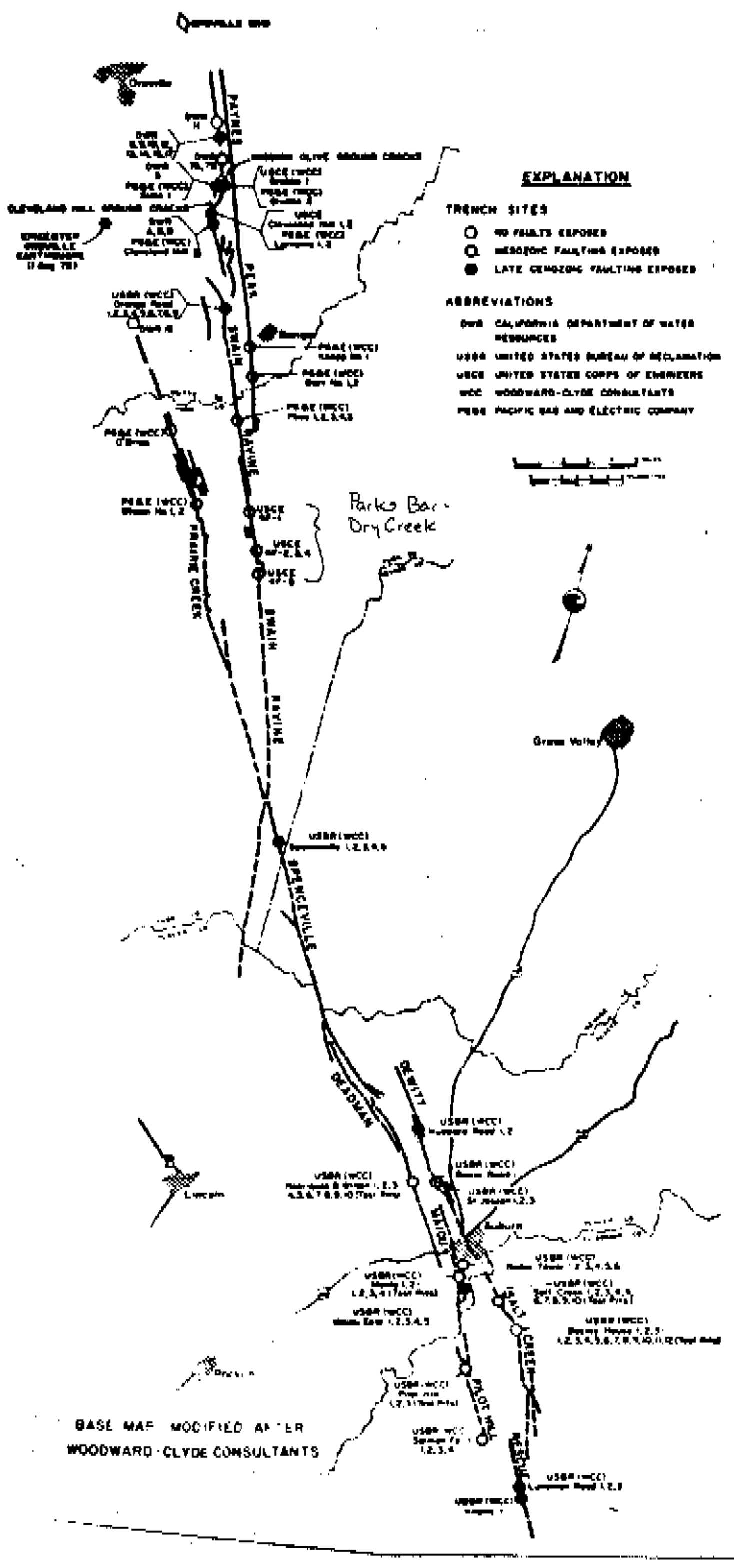

Figure 1 (to FER-146). Northern extension of the Bear Mountain fault zone, showing the Swain Ravine, Spenceville, and Dewitt fault zones evaluated in this FER. Locations of geologic investigations by CDWR, Woodward-Clyde, and U.S. Army Corps of Engineers are also shown. Map from CDWR, 1979.

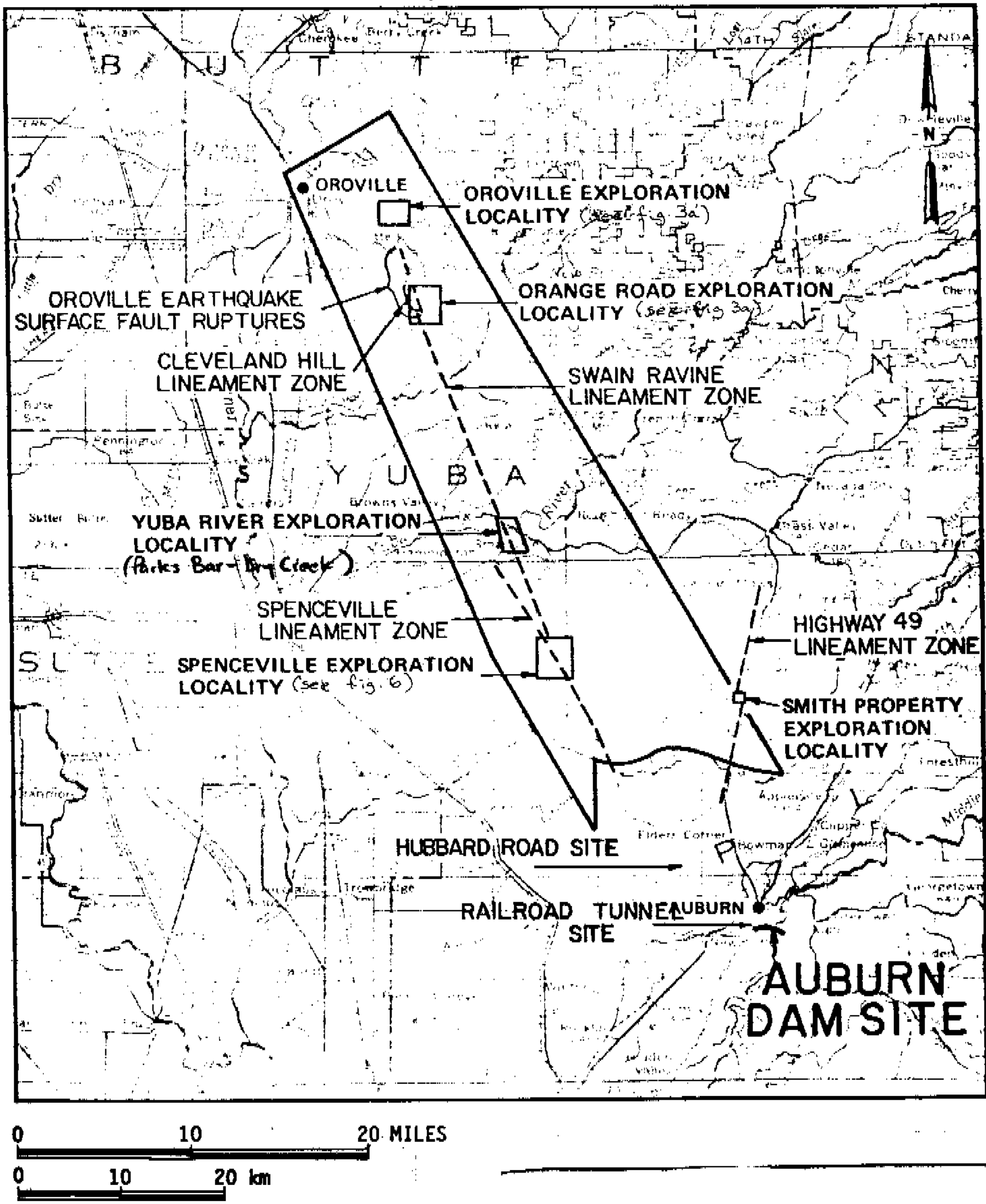

Figure 2a (to FER-146). Generalized map of the Swain Ravine and Spenceville fault zones, showing locations of site specific investigations conducted by Woodward-Clyde (Schwartz, et al, 1977). Refer to appropriate figure for detailed map of site.

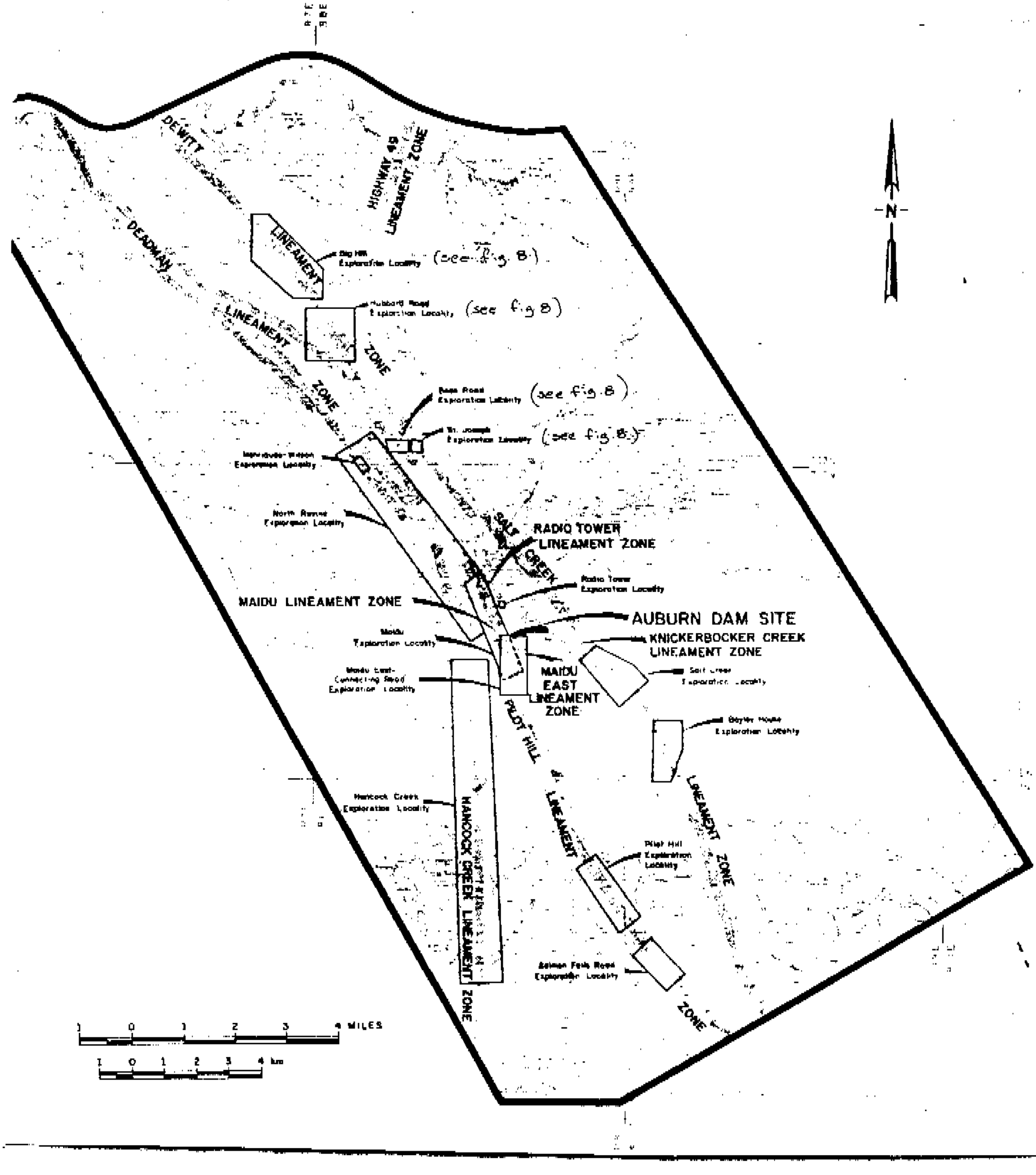

Figure 2b (to FER-146). Generalized map of the Dewitt fault zone, showing locations of site specific investigations conducted by Woodward-Clyde (Schwartz, et al, 1977). Refer to appropriate figure for detailed maps of site.

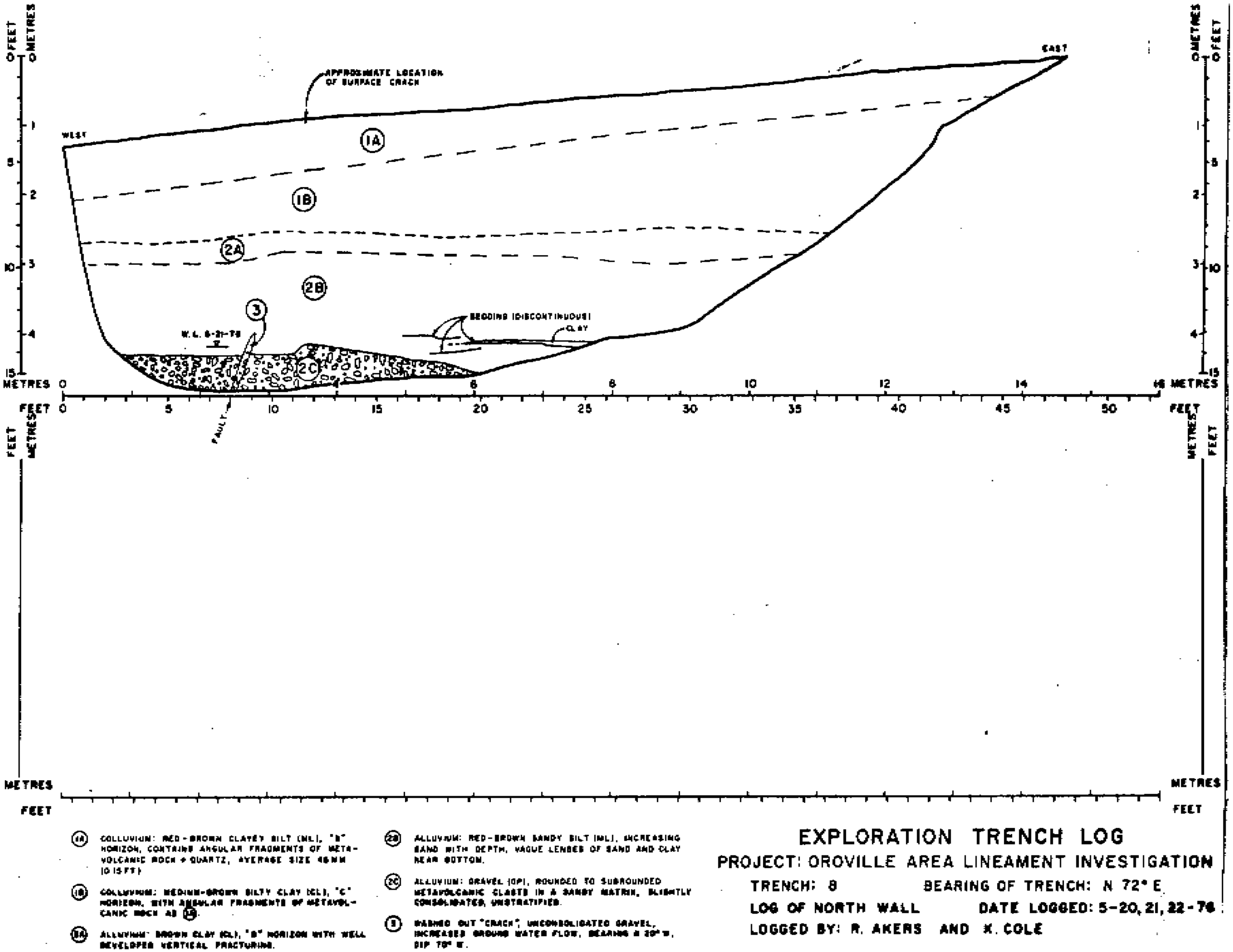

Figure 4b (to FER-146). Log of trench T_8 excavated by CDWR (1979).

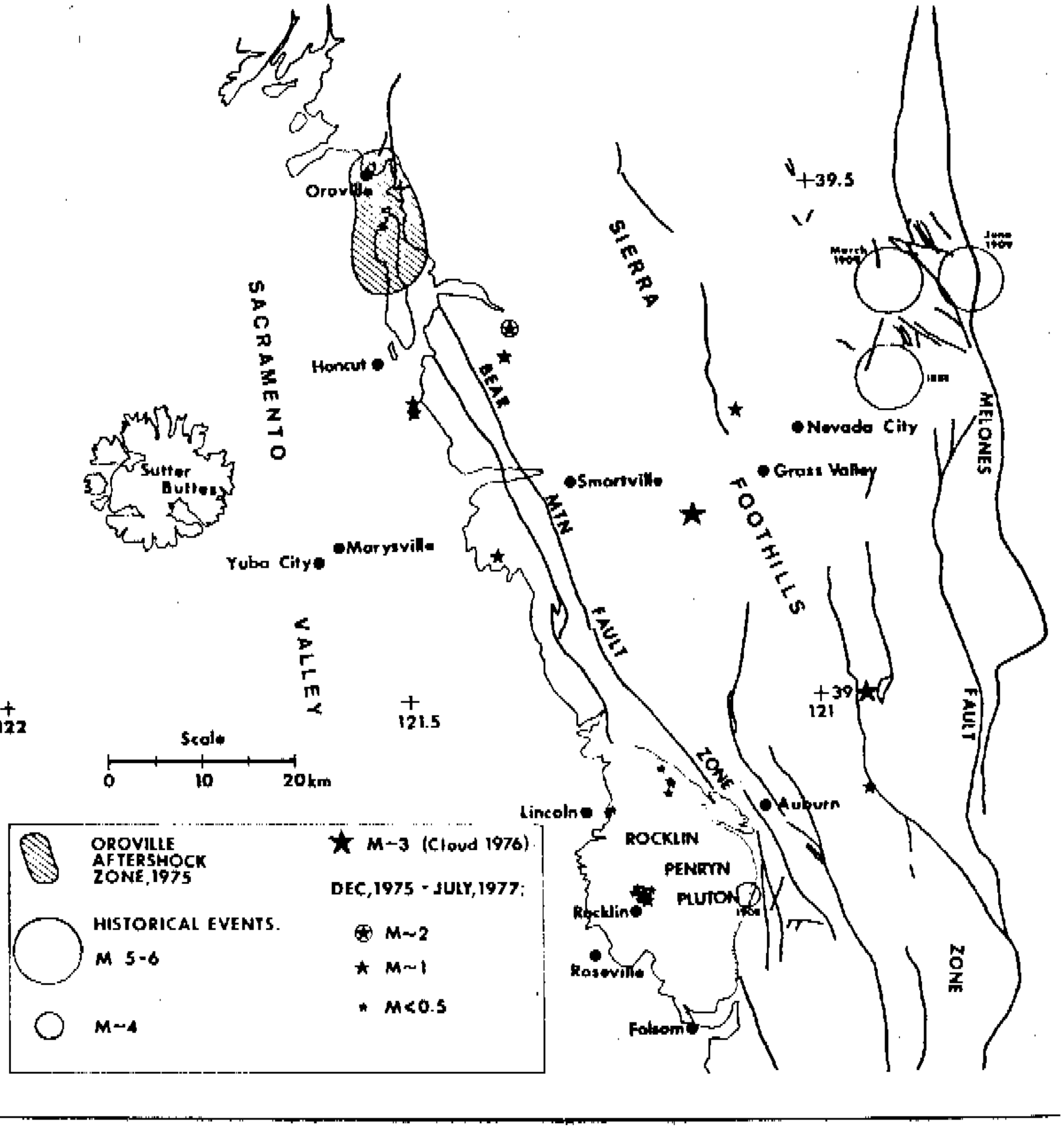

Figure 10 (to FER-146). Map of northern part of Foothills fault system, showing known earthquakes between Oroville and Folsom. Map from Cramer, et al. (1978).